

Natural and Nature-Based Features in the USACE North Atlantic Coast Comprehensive Study

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PIANC WwN Workshop

1 June 2014



US Army Corps of Engineers
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Hurricane Sandy

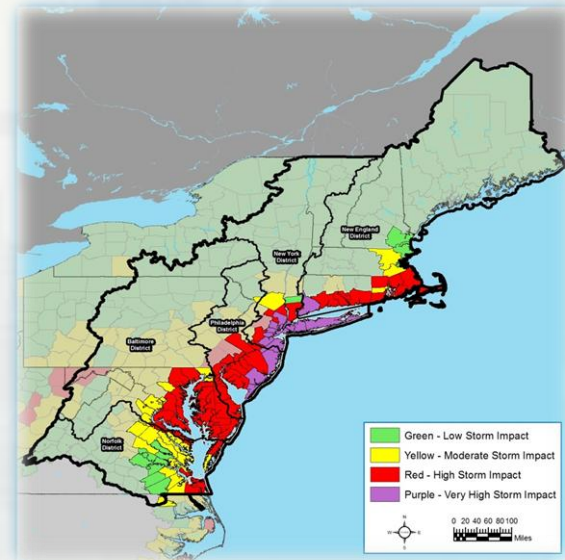
Storm Impacts and Damages:

► Human

- 286 people killed (159 in the US)
- 500,000 people affected by mandatory evacuations
- 20,000 people required temporary shelter
- Extensive community dislocations
 - continuing today in some areas

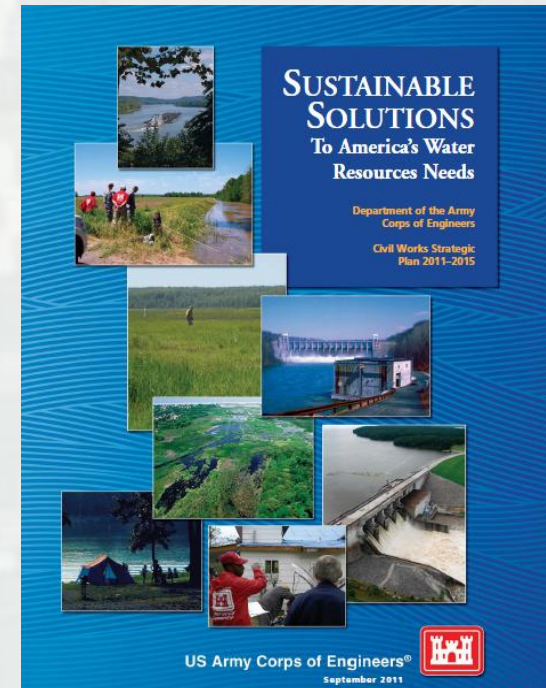
► Economic

- \$65B in damages in the U.S.
- 26 states affected (10 states and D.C are in the NACCS study area)
- 650,000 houses damaged or destroyed



In the Context of Coastal Resilience...

- What opportunities are there for achieving better alignment of natural and engineered systems?
 - ▶ Can improved alignment reduce risks to life and property?
 - ▶ What additional services can be produced?
 - ▶ What are the science and engineering needs in order to achieve better alignment?



Sustainable Solutions Vision: "Contribute to the strength of the Nation through innovative and environmentally sustainable solutions to the Nation's water resources challenges."



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Systems: Coastal Risk Reduction and Resilience

“The USACE planning approach supports an **integrated approach** to reducing coastal risks and increasing human and ecosystem community resilience through a combination of **natural, nature-based, non-structural and structural measures**. This approach considers the engineering attributes of the component features and the dependencies and interactions among these features over both the short- and long-term. It also considers the **full range of environmental and social benefits** produced by the component features.”

Coastal Risk Reduction and Resilience: Using the Full Array of Measures



US Army Corps of Engineers
Directorate of Civil Works



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September 2013
CWTS 2013-3



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Natural and Nature-Based Infrastructure at a Glance

GENERAL COASTAL RISK REDUCTION PERFORMANCE FACTORS:
STORM INTENSITY, TRACK, AND FORWARD SPEED, AND SURROUNDING LOCAL BATHYMETRY AND TOPOGRAPHY



Dunes and Beaches

Benefits/Processes

- Break offshore waves
- Attenuate wave energy
- Slow inland water transfer

Performance Factors

- Berm height and width
- Beach Slope
- Sediment grain size and supply
- Dune height, crest, width
- Presence of vegetation



Vegetated Features:

Salt Marshes, Wetlands, Submerged Aquatic Vegetation (SAV)

Benefits/Processes

- Break offshore waves
- Attenuate wave energy
- Slow inland water transfer
- Increase infiltration

Performance Factors

- Marsh, wetland, or SAV elevation and continuity
- Vegetation type and density



Oyster and Coral Reefs

Benefits/Processes

- Break offshore waves
- Attenuate wave energy
- Slow inland water transfer

Performance Factors

- Reef width, elevation and roughness



Barrier Islands

Benefits/Processes

- Wave attenuation and/or dissipation
- Sediment stabilization

Performance Factors

- Island elevation, length, and width
- Land cover
- Breach susceptibility
- Proximity to mainland shore



Maritime Forests/Shrub Communities

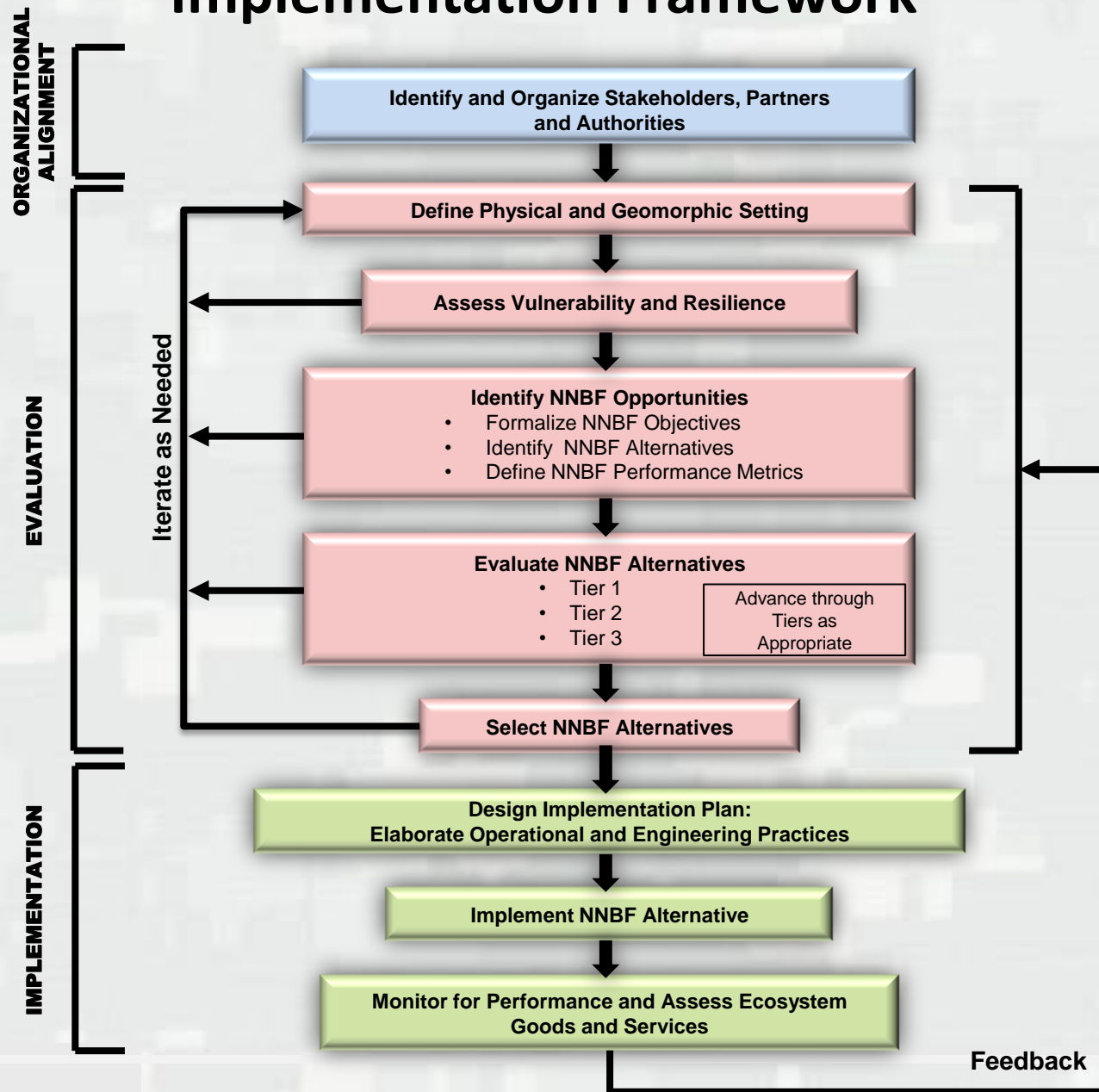
Benefits/Processes

- Wave attenuation and/or dissipation
- Shoreline erosion stabilization
- Soil retention

Performance Factors

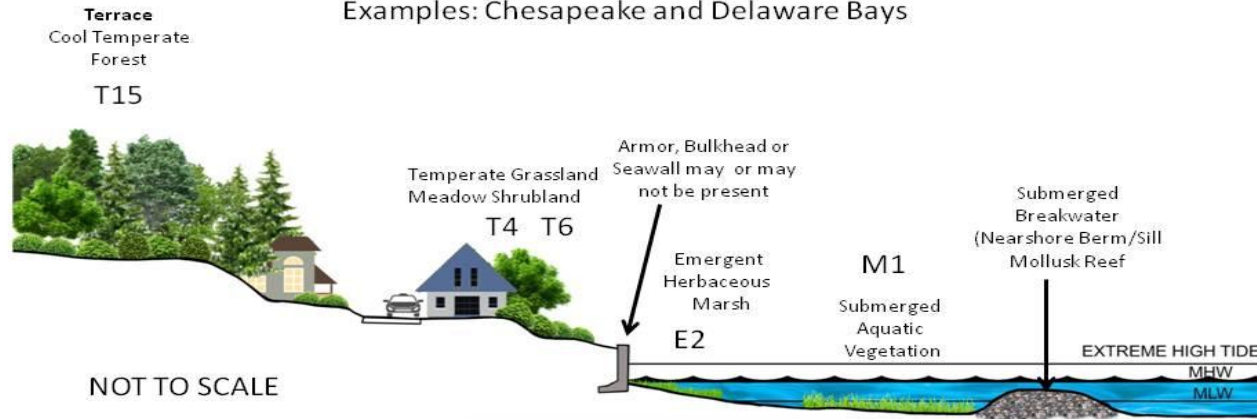
- Vegetation height and density
- Forest dimension
- Sediment composition
- Platform elevation

Natural and Nature-Based Features Evaluation and Implementation Framework



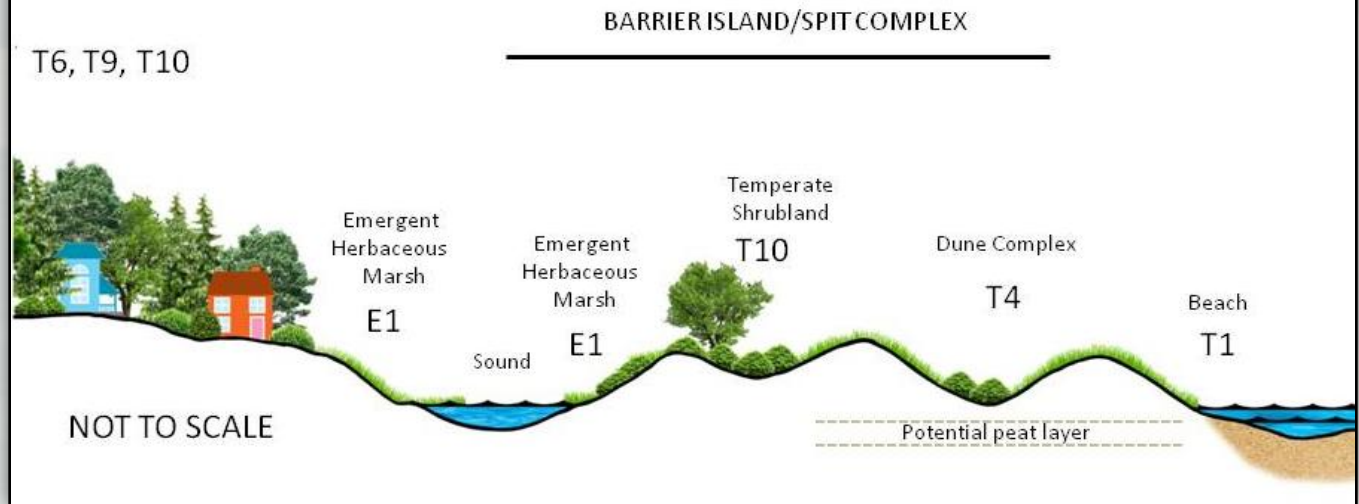
1 A 1-1. Drowned River Valley

Examples: Chesapeake and Delaware Bays



II B 1. Marine Depositional Barrier Coast

Examples: Virginia coast



Resilience

COMMENTARY:

Changing the resilience paradigm

Igor Linkov, Todd Bridges, Felix Creutzig, Jennifer Decker, Cate Fox-Lent, Wolfgang Kröger, James H. Lambert, Anders Levermann, Benoit Montreuil, Jatin Nathwani, Raymond Nyer, Ortwin Renn, Benjamin Scharte, Alexander Scheffler, Miranda Schreurs and Thomas Thiel-Clemen

Resilience management goes beyond risk management to address the complexities of large integrated systems and the uncertainty of future threats, especially those associated with climate change.

The human body is resilient in its ability to persevere through infections or trauma. Even through severe disease, critical life functions are sustained and the body recovers, often adapting by developing immunity to further attacks of the same type. Our society's critical infrastructure — cyber, energy, water, transportation and communication — lacks the same degree of resilience, typically losing essential functionality following adverse events. Although the number of climatic extremes may intensify or become more frequent, there is currently no scientific method available to precisely predict the long-term evolution and spatial distribution of tropical cyclones, atmospheric blockages and extratropical storm surges, nor are the impacts on society's infrastructure in any way quantified. In the face of these unknowns, building resilience becomes the optimal course of action for large complex systems.

Resilience, as a property of a system, must transition from just a buzzword to an operational paradigm for system management, especially under future climate change. Current risk analysis methods identify the vulnerabilities of specific system components to an expected adverse event and quantify the loss in functionality of the system as a consequence of the event occurring. Subsequent risk management has focused on hardening these specific system components to withstand the identified threats to an acceptable level and to prevent overall system failure.

Two factors make this form of protection unrealistic for many systems. First, increasingly interconnected social, technical and economic networks create large complex systems and the risk analysis of many individual components becomes cost and time prohibitive. Second, the uncertainties

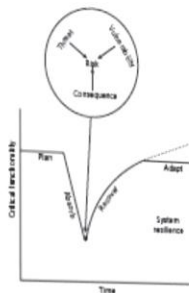
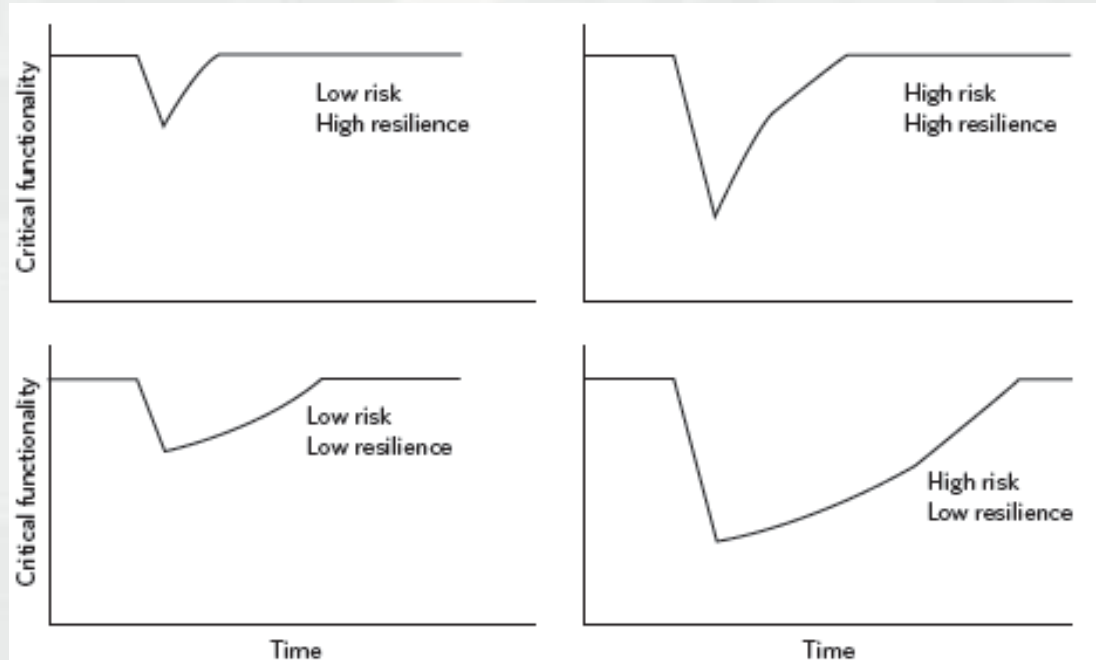


Figure 1 A resilience management framework includes risk analysis as a central component. Risk analysis depends on characterization of the threats, vulnerabilities and consequences of adverse events to determine the expected loss of critical functionality. The National Academy of Sciences definition of resilience places risk in the broader context of a system's ability to plan for, recover from and adapt to adverse events over time. In the system functionality profile, risk in a system is interpreted as the total reduction in critical functionality and the resilience of the system is related to the slope of the absorption curve and the shape of the recovery curve — indicating the temporal effect of the adverse event on the system. The dashed line suggests that highly resilient systems can adapt in such a way that the functionality of the system may improve with respect to the initial performance, enhancing the system's resilience to future adverse events.

NATURE'S CLIMATE CHANGE | VOL 4 | JUNE 2014 | www.nature.com/natureclimatechange

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opinion & comment



Igor Linkov, Todd Bridges, Felix Creutzig, Jennifer Decker, Cate Fox-Lent, Wolfgang Kröger, James H. Lambert, Anders Levermann, Benoit Montreuil, Jatin Nathwani, Raymond Nyer, Ortwin Renn, Benjamin Scharte, Alexander Scheffler, Miranda Schreurs and Thomas Thiel-Clemen. 2014. Changing the Resilience Paradigm. *Nature Climate Change* 4: 407-409.



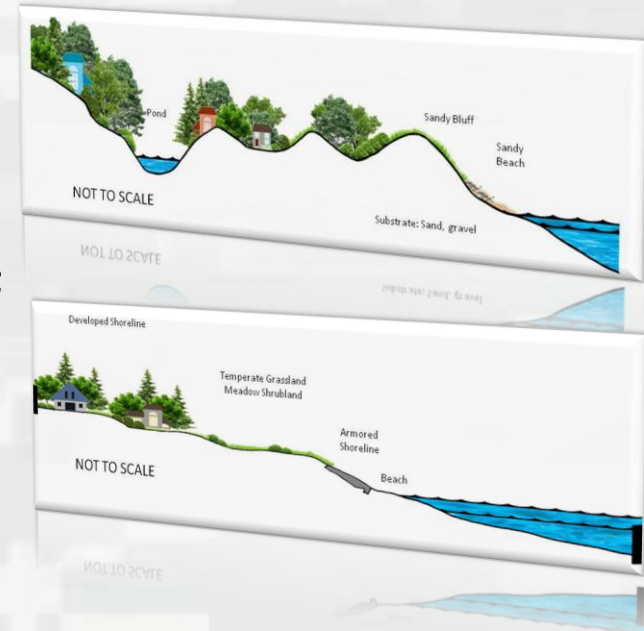
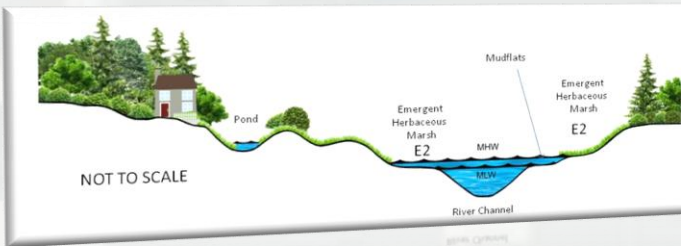
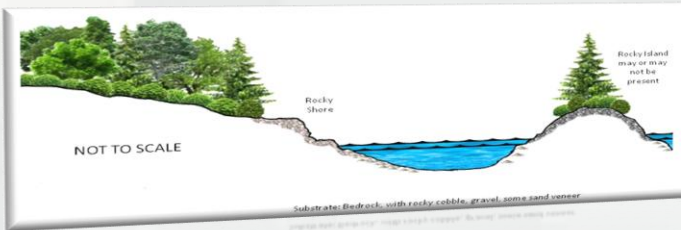
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Vulnerability

Vulnerability wrt Nature-Based Features
in the Coastal Zone



Relative
vulnerability of
coastal landscapes;
how nature-based
features affect
vulnerability



***Vulnerability:** Degree to which a system is susceptible to, and unable to cope with, adverse effects from a hazard; vulnerability is a function of the character and magnitude of a hazard to which a system is exposed, its sensitivity, and its adaptive capacity.*

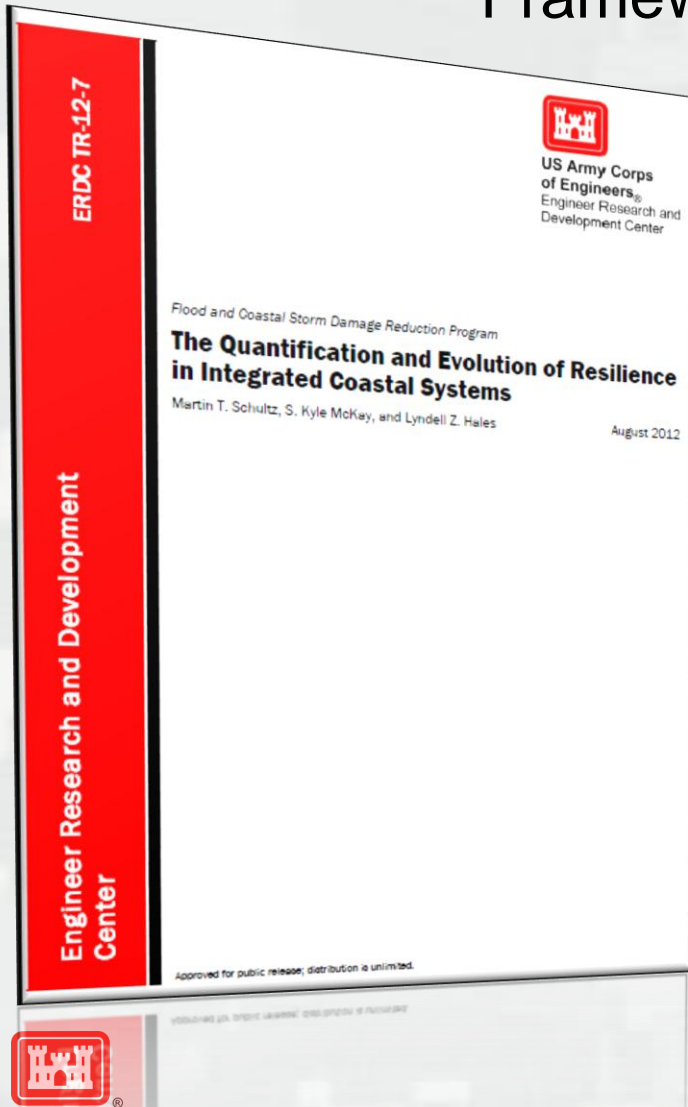


Resilience

Framework to quantify resilience for Integrated Coastal Systems (ICS)



- Focus on functional performance of engineered projects.
- Incorporates multiple projects in the ICS.
- Develops a quantified measure of resilience based on speed and magnitude of restoring functionality or service following a disturbance.
- Functionality/service can be restored via **natural processes** and/or human maintenance.
- Not limited by mission area.

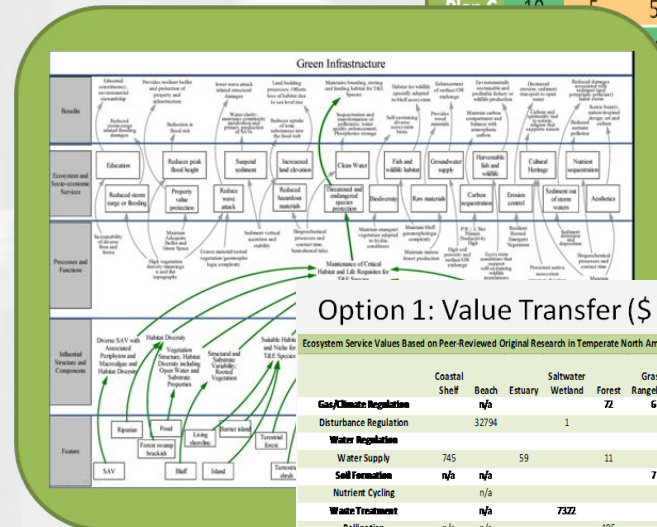


System Performance Evaluation

- **Level 1** – Qualitative characterization of performance
- **Level 2** – Semi-quantitative characterization of performance
- **Level 3** – Quantitative characterization of performance

72 individual performance metrics identified for NNBF

Wt	1	2	4	3	5		
	B1	B2	B3	B4	B5	Mean	Wtd
Plan A	10	8	5	1	0	4.8	49
Plan B	10	10	0	0	0	4	30
Plan C	10	5	5	9	7	7.2	102
Plan D	10	8	5	10	10	7.8	115
Plan E	4	7				5.6	80

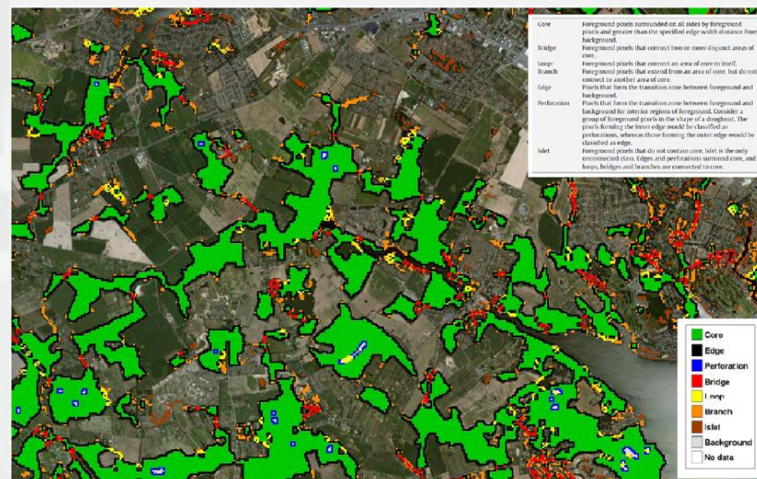


Option 1: Value Transfer (\$ Value per acre)

Ecosystem Service Values Based on Peer-Reviewed Original Research in Temperate North America/Europe (2012 \$/ac*yr)

	Coastal Shelf	Beach	Estuary	Saltwater Wetland	Forest	Grass/Rangelands	Cropland	Freshwater Wetland	Open Fresh Water	Riparian Buffer	Urban Greenspace	Urban/Barren
Gas/Climate Regulation												
Disturbance Regulation	32794			1						106		
Water Regulation								7162				7
Water Supply	745		59		11			1396	492	2310		
Soil Formation	n/a	n/a				7			n/a			
Nutrient Cycling	n/a	n/a										
Waste Treatment	n/a	n/a		7322								
Pollination	n/a	n/a			195		10		n/a			
Biological Control	n/a	n/a										
Habitat/Refugia			438	277	1110			6				
Aesthetic/Recreation	17651	364	31	356	1	18	1889	428	1047	2562		

Option 2: Ecosystem Production Functions



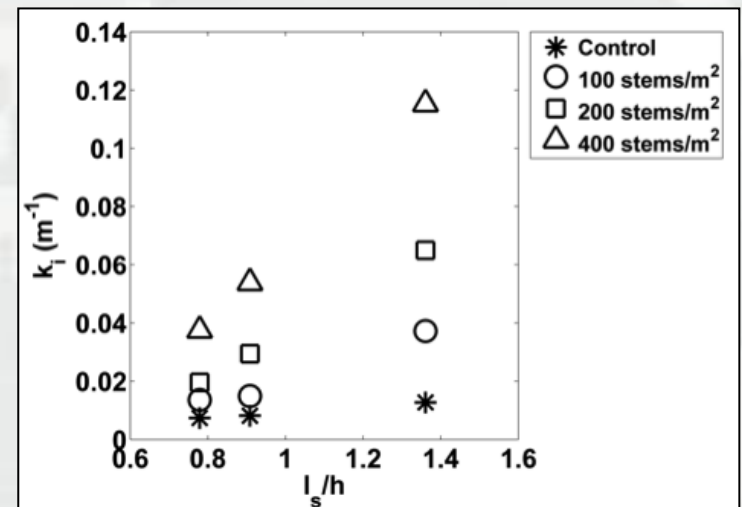
Literature, and Meta-analysis Studies in Temperate North America/Europe (2012 \$/ac*yr)

	Forest	Grass/Rangelands	Cropland	Freshwater Wetland	Open Fresh Water	Riparian Buffer	Urban Greenspace	Urban/Barren
65		4		361			404	
				4397		106		
		2		3590			7	
196				1856		492	2310	
6		4				n/a		
53		53		1008				
195		16	10			n/a		
2		14	14					
			999	136				
147		1	18	1680	428	1047	2562	
1				1070		5		



Example: Wave Dampening by Wetlands

- What are the engineering benefits of wetlands with respect to waves?
- Flume studies being performed in the 10 ft flume
 - Complemented by examination of sediment processes and field studies
- Wave attenuation was found to:
 - increase with stem density
 - increase with submergence ratio
 - slight increase with incident wave height
- Results used to update STWAVE



Assessing vulnerability and resilience over the long term: performance metrics



Dunes and Beaches

Benefits/Processes

Break offshore waves
Attenuate wave energy
Slow inland water transfer

Performance Factors

Berm height and width
Beach Slope
Sediment grain size and supply
Dune height, crest, width
Presence of vegetation



Vegetated Features:

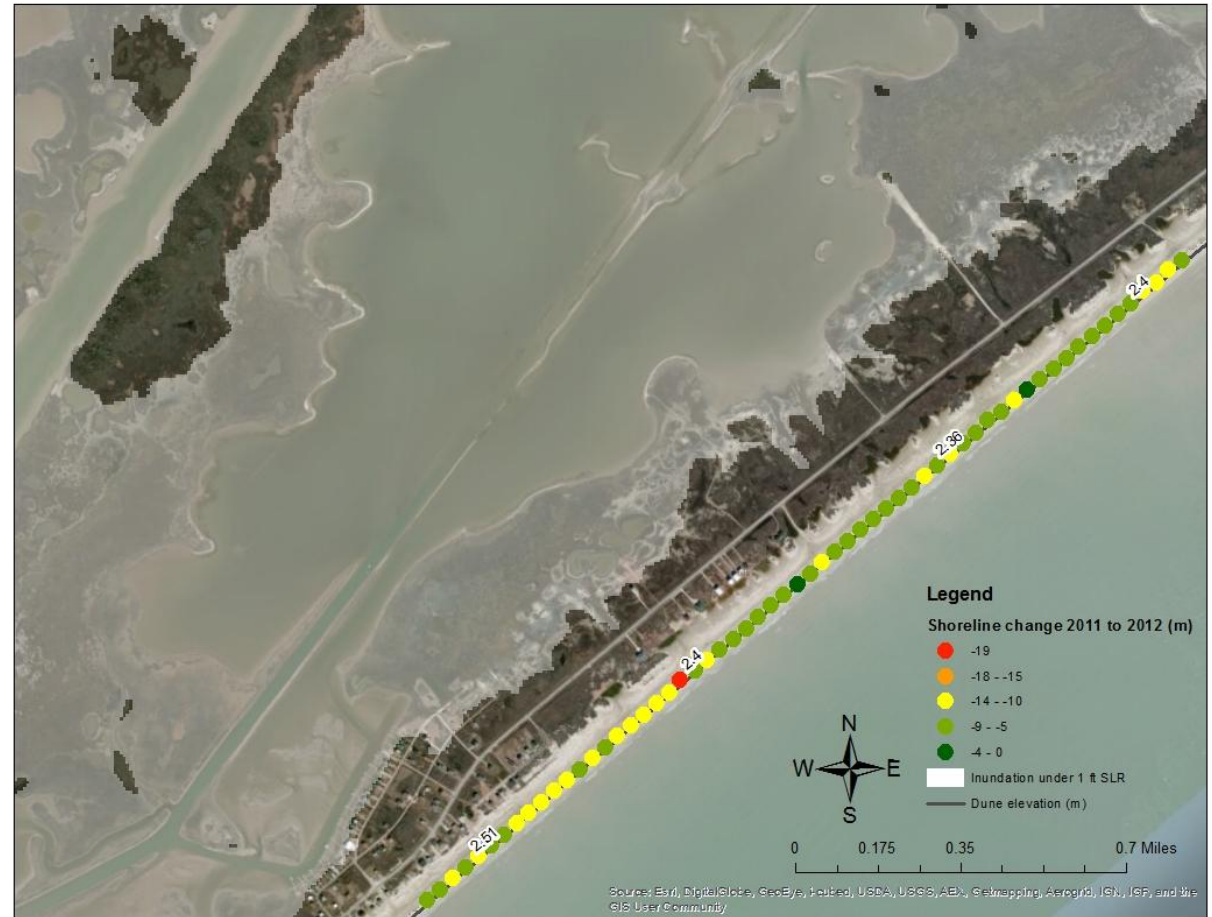
Salt Marshes, Wetlands, Submerged Aquatic Vegetation (SAV)

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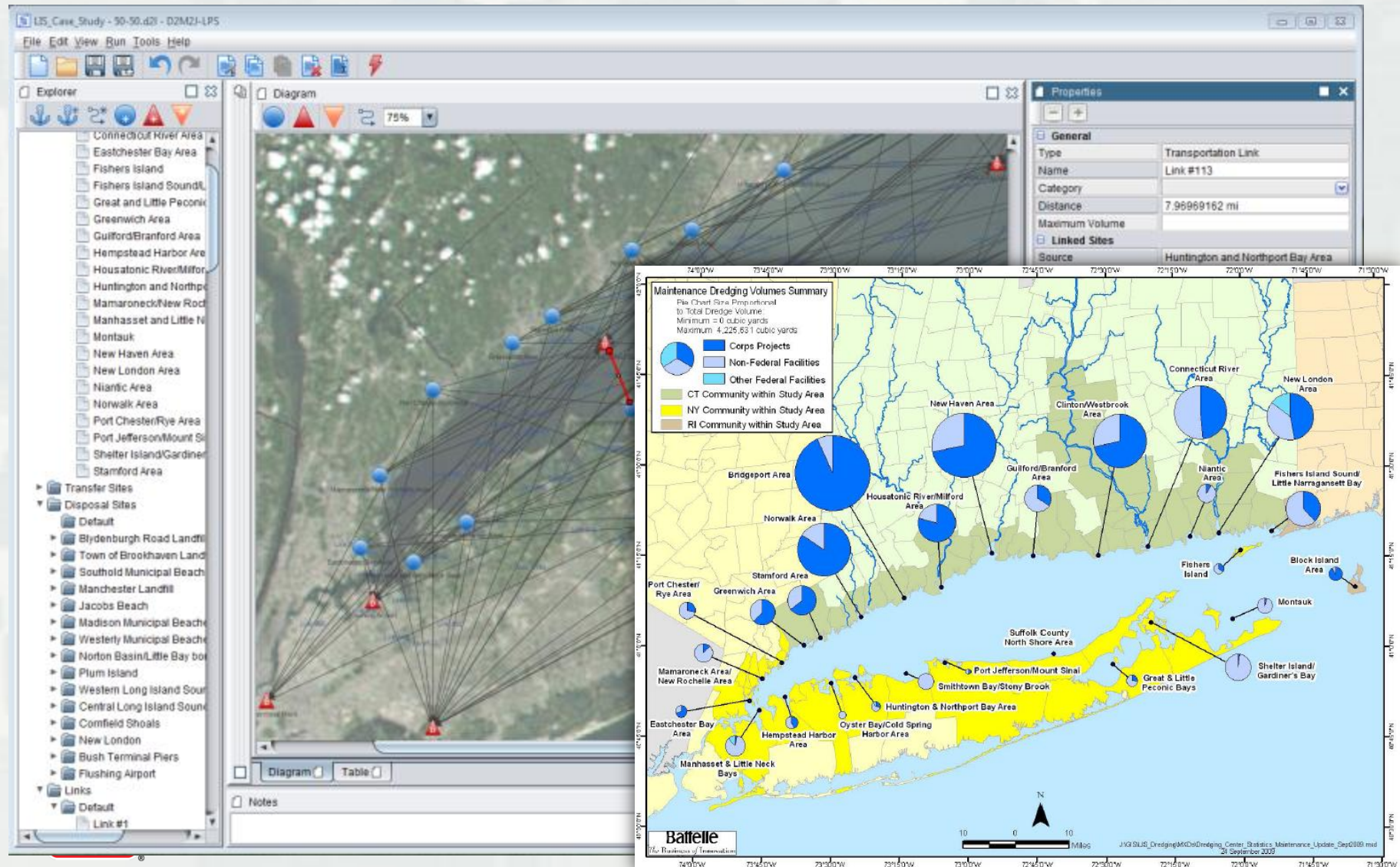
Inundated under 1 ft of RSLR

Drum Bay, Follets Island



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D2M2: Dredged Material Management Decisions



Performance Evaluation Case Studies

- **Proof of concept analysis**
 - Quantify benefits of environmental restoration projects using an ecosystem goods and services (EGS) analysis framework
- **Hurricane Sandy case study**
 - Use extreme event to improve understanding of restoration effectiveness & benefits
- **Focused on two general types of services:**
 - Flood damage Reduction
 - Wildlife Habitat (emphasis on T&E species)
- **3 Study Sites**
 - Jamaica Bay
 - Cape May Meadows
 - Cape Charles South



Moving Forward. . .

- Organize and expand science and engineering related to natural processes and features
 - ▶ Reduce uncertainties regarding design and performance of NNBF
 - ▶ Understand dynamic performance of NNBF
 - ▶ How to effectively integrate NNBF with other measures
- Integrating expertise across disciplines and organizations
 - ▶ Planning, designing, constructing, operating, monitoring, and maintaining integrated systems

